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Notes on Street Main Laying.

Thesis for M. E. Degree.

W. Musgrave Wood.
Class 1897.

May 1903.

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In the planning or locating of prospective street mains, a great deal of importance should be attached to the future as well as the present conditions. The use of gas is increasing in some districts at the rate of twenty or thirty per-cent a year, and as the life of a cast iron main is easily fifty years, the capacity is an important item in determining the size for future requirements.

All main work is classified as follows. Bettering Conditions Increasing Pressure, New Business and Ahead of Paving.

A number of large mains have been and are being laid to increase the pressure at the

low pressure points, localities where the supply of gas is so poor that the pressure falls off considerably during the early evening. The localities are found by going systematically over the whole district with recording pressure gauges, during the time of heaviest consumption.

The object of the large mains is to equalize the pressure. We undertake to supply gas to the burners at a pressure ranging between 40 and 25 tenths inches of water.

Owing to the cost of paving it is considered economical to either overhaul existing mains or lay new ones where business prospects warrant it, upon all

streets prior to paving or repaving.

In the locating of a street main laid for any of the above reasons there are several conditions to be considered. 1st Present or future consumers. 2nd. Necessity for a feeder through the street. 3rd. If the location of an existing main has no very serious objections, by laying the new main in the same location, the old pipe is recovered and the service connections are easily made. Proximity to parallel sewers, conduits or water pipes should be avoided. both on account of the softness of the old ditch and also on account of disturbance by other companies doing repair works.

Other things being equal. the side with the most services should be chosen excepting one condition.

If one side of the street is built up and there are good prospects for building the other side after the paving has been laid, the main should be laid on the opposite side from the houses. This allows the long services crossing the street to be laid ahead of Paving.

The street should be graded and the curbs set in order to get the line of pipe at a uniform distance from the curb and a uniform depth.

In some cases where the grade is uncertain except at the intersecting streets the following

method is employed to get a uniform grade for the pipe.

At each end of the line near the curb, if there is one, where the proper street level can be gotten is set up a "target" consisting of a strip of wood held vertically by burying one end several inches in the ground. The tops of the "targets" are placed five (5) feet above the level of the street.

Another target is cut of such a length that when placed so that the top comes in a line with the others, determined by sighting over the tops of all three, the bottom will give the proper depth to which the trench should be dug.

If the ditch is to be 4 feet

deep a nine foot target is used.
This third target is then placed at intervals along the trench, giving the men the line for an even bottom.
This is much more simple than using a level as the grade has to be allowed for at every "set up."
In planning the intersections of cross streets where the neighborhood is built up, outlets for prospective mains should be left and the location of these outlets decided upon by the same considerations as the location of the original line that is prospective business location of sewers, water pipes conduits etc. If the locality is not built up, an inspection

of the city plans will show proposed sewers and the way the building lots are laid out. The corners from which the gable ends of the houses run should be left without outlets as no services are required. The intersecting pipes should be laid several feet outside the line of new paving which usually goes to the house lines on cross streets.

Footway locations should seldom be used unless the distance from the curb to the house is considerable. Complaints from property owners for breaking footway paving will overbalance the saving of short services.

On short runs in alleys where the street is asphalted the sidewalk would be preferable for wrought iron pipe. Cast iron should not be laid less than ten feet from the house line on account of gas from the leaking joints finding its way into cellars.

In regard to the size of the mains, all smaller sizes are selected on account of their strength rather than their capacity. In some places two (2) inch wrought iron pipe is laid on short runs to supply street lamps or a few consumers where there is no prospect for more business, other than this wrought iron

is seldom used. No cast iron pipe smaller than four (4) inch diameter is being laid in Philadelphia and that size is used only upon tramway streets with very little traffic. Six (6) inch pipe is the standard size for general distribution this is heavy enough to stand the various strains put upon it by settling ground, heavy traffic etc.

The advantages of cast iron as compared with wrought iron pipes for use as gas mains are: greater ability to withstand any corrosive action of the soil in which it is laid, and consequently longer life; greater thickness for equivalent internal diameters

giving a better and cheaper joint for the service connections tapped directly into the main; and in sizes six inch and over smaller first cost. The disadvantages of cast iron pipe are: the necessity for a greater number of joints of a form more difficult to make tight originally and to keep tight throughout the life of the pipe. than is the form of joint used in wrought iron pipe; and the brittleness of cast iron which renders it liable to break under shocks from extraordinary traffic on the street in which it is laid or from strains thrown upon it through subsidences.

Wrought iron pipe is laid in lengths varying from eighteen

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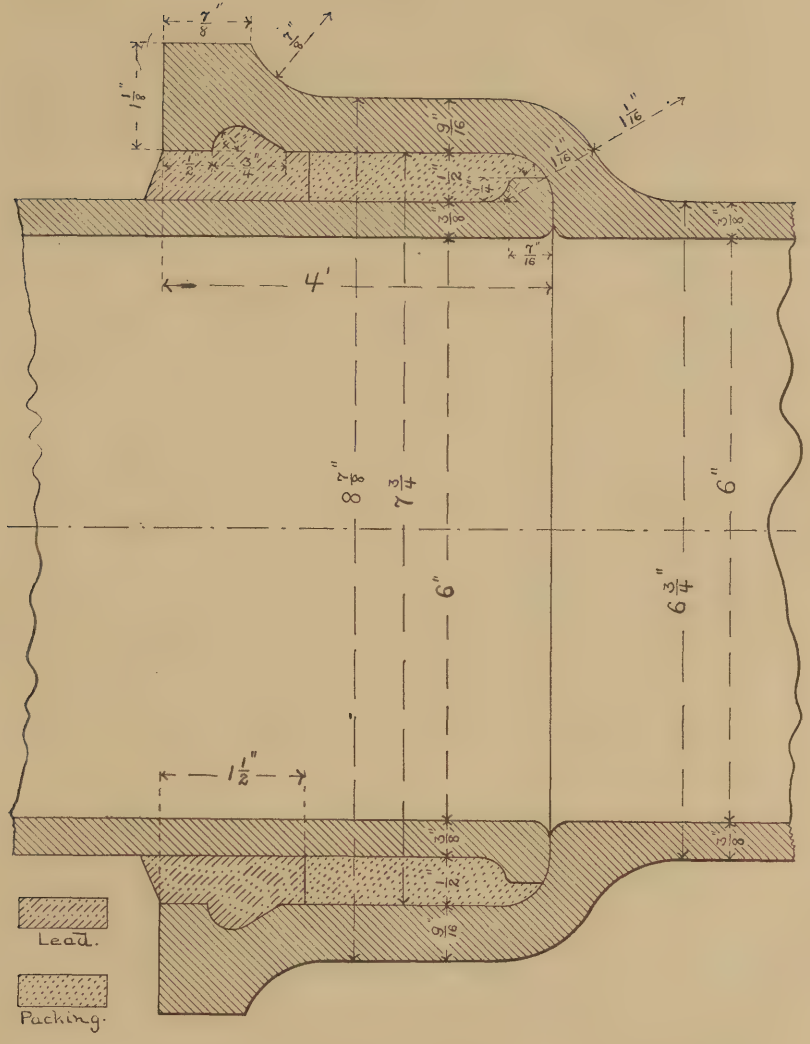
to twenty five (25) feet with screw-thread joints. If properly entered and screwed up tight there is not one chance in a thousand of a leak, under gas pressure, either when first put in or developing later. On the other hand cast iron pipe is made in twelve foot lengths or about half as long as wrought iron, and being laid with the "bell and spigot" joints, not only take considerable time to make tight when laid but are liable to leak more or less after the first winter under ground.

The quality of cast iron is very irregular and each shipment of pipe should be examined. The iron, when

fractured should show a dull gray color and not sparkle or glisten. Such pipe being softer (softer) will work easier and stand greater strains than the pipe of lighter color. It should be uniform in thickness and free from blow-holes or cavities.

It has been the custom to cast pipe with the bell end down. The blow holes and bad metal will then rise to the spigot end where it can be cut off before laying the pipe.

This practice seems to have changed in some instances as we can see on the face of the bells of our new six inch pipe the remains of six small gates showing that the length has



Section of 6 in. Bell, Spigot and Lead Joint.

American Gas Light Association Standard.

been cast with the bell end up. This is probably because the foundrymen have learned how to cast pipe without having so many blow holes. The almost universal joint used with cast iron pipe is the bell and spigot, see illustration.

The joint space is filled with jute packing or hemp yarn and Portland Cement or lead.

In the sketch the joint is shown made with lead.

The depth of the bell, for pipe ranging from 3 inches to 8 inches diameter is 4 inches. For larger sizes it is slightly deeper, 30 inch pipe having a 5 inch bell.

In making a lead joint in a cast iron main, the first step

in the operation is to insert the spigot end of one length in the bell of the other, and drive the length home. Then line it up and fix in place by tamping a little dirt around the middle of the pipe. Next fill solidly with packing part of the joint between the bell and spigot as shown in the sketch. A sufficient number of strands of packing should be twisted together forming a rope a trifle larger in diameter than the width of the joint space. This rope should be cut into pieces of such a length that the ends will butt when placed <u>twice</u> around the spigot and pulled up tight.

One of these pieces is used to

lift the spigot end as it is inserted into the bell of the pipe previously laid, and is sent home with it. thus keeping the spigot central in the bell and avoiding the necessity of wedging it up after it is in place. This piece of packing is then driven solidly into place in the bottom of the joint space by means of a three pound caulking hammer and packing iron and other pieces are inserted one at a time and each driven home, a sufficient number being used to fill the joint space to the required depth leaving 1½ inches for the lead. The band, consisting of a strip of rubber packing about one inch square in cross section

with a screw clamp to attach the ends together is then placed around the spigot end of the pipe and driven up solid against the face of the bell being set so as to leave the opening between the ends of the band at the top. Around this opening a red clay dam is formed making a gate to pour in the molten lead. The lead is melted in a large gasoline furnace or coke fire and should be hot enough to char the end of a dry stick. It is poured into the joint rapidly to keep it from chilling and until the gate is filled up level. After removing the band the lead is driven back or caulked with caulking tools starting with a cold

chisel and increasing the driving face by increments of 1/16 inch in thickness until the last tool exactly fills the joint and cuts off the extra lead against the face of the bell.

This is the usual method of making all lead joints used either for water or gas mains although it is a very delicate joint and very easy to disturb. A sharp blow with a hammer on the side of the bell will cause it to leak, or the least settlement of the pipe will have the same effect.

We - that is the Spring Garden District of the U.G.I. Co. made a few experiments this last winter on various lines to improve this joint if possible.

For about ten weeks starting last

January. I was employed examining sixty seven (67) joint ranging in size from 20 to 30 inches diameter. and found only eight of them were tight although a large number of them had been recaulked less than two years previously. From 39 of these the old lead was cut out and replaced by refined lead. The idea being that a soft lead could be driven back and upset more in the joint. A short series of tests were made by Mr G. I. Vincent to find the softests brand.

He moulded five different brands of lead into small columns. One inch in diameter and two inches long. These were then squeezed upon the Riehle machine with the following results:

Specimen.	Mean 1st Test. Lbs.	Mean 2nd Test. Lbs	Finial Thickness Inches	2nd Test Corrected to .262" thick. Lbs.
Old Pig Lead.	7025	54000	.257	52960.
Old Meter Connections	7375	52000	.258	51210.
Old Lead Joints.	7360	64000	.244	59600
Tatems Refined Ingot.	6675	54000	.255	52560
National - Nathan Trotter	7790	52200	.274	54590
Omaha - Nathan Trotter.	6600	42500	.283	45910

The first column gives the pounds pressure required to compress the column of lead from 2" to 1 inch in length. The second is the reading after compressing to about .25 inches The actual thickness being given in the third column. In the fourth is the second test corrected to a uniform thickness assuming that the variation for such a short distance would be along a straight line.

Tatems Refined Ingot lead was

the brand used on our test joints in the street. We also made another test of several varieties making up a joint each under a split sleeve and caulking it with a 3 lb and 8 lb hammers to find out how far back the lead was upset. Upon removing the split sleeve we found very little difference if any between the soft or hard lead or between the 3 lb or 8 lb hammers. They all seemed to be upset about 1¼ inches back of the face of the bell. The lead had been run in three inches deep.

From the examination made of the above sixty seven joints Eight were tight. Seventeen were apparently badly caulked originally

and the remaining forty two were apparently leaking solely on account of the longitudinal contraction of the pipe owing to the decrease in temperature from summer to winter. A test was made of the lateral contraction to see if that would effect the joint as the coefficient of expansion of lead is about 2½ times that of iron. Authorities differ as to the varieties of lead.

Four twenty inch joints were made up and afterward heated to about 280° F. by a small fire beneath the pipe. A pressure of eight inches mercury column was then placed upon the joints but they still held tight. After they had cooled off again we obtained

the same results showing that the difference in coefficient of expansion does not cause the trouble.

The shrinkage in the length of pipe is apparently what causes the leak. as it has to be done by pulling the spigot end out of the joint and thus distroying the lead contact.

A series of tests were made by placing recording thermometers giving maximum and minimum reading at various depths below several kinds of paving in order to determine the range of temperature changes which affect our mains. The results of these tests are given below. These thermometers were set in the Fall of 1901 and removed one year later

— means thermometer did not register

TEMPERATURE READINGS. FARENHEIT SCALE

KIND OF PAVING.	DEPTH BELOW SURFACE	NORTH SIDE OF STREET		SOUTH SIDE OF STREET		TOTAL VARIATION	
		MAX.	MIN.	MAX.	MIN.	NORTH SIDE	SOUTH SIDE
	FT.						
ASPHALT. BROKEN STONE BASE	3'	73½°	21°	75½°	–	52½°	–
" " " "	4'	73°	–	72°	27½°	–	44½°
CLAY SURFACE – NO PAVING.	2'	80½°	30°	77½°	25°	50½°	52½°
" " " "	3'	76½°	32½°	74½°	–	44°	–
" " " "	4'	74½°	33½°	73°	35°	41°	38°
" " " "	5'	75°	–	74½°	37½°	–	37°

Discarding the reading at five feet depth as few mains are laid at that depth. the average variation between Winter and Summer is 46° F.

Now by taking the coefficient of expansion of Cast iron from "Kent" as .00.000.556 a 12 foot length of pipe would contract .0368 inches (about $\frac{1}{32}$") for a drop of 46° F. which evidently would affect the joint.

The only alternative we have at present for the lead is Portland cement. A joint of cement is made up in the following way. A single piece of the rope packing is driven to the back of the joint. in the same way as when lead is used. It is the practice in this district to "grout" the yarn. which allows it to be packed harder. It also keeps the yarn from absorbing any moisture from the cement. which would cause it to dry out and not set properly. The Cement used should be some brand of quick setting hydraulic cement. The United Gas Imp. Co after a series of tests have decided the "Red Star Portland" holds first place. This should be

mixed neat, with one part water to three and a half parts cement. This quantity varies both with the quality of the cement and the condition of the atmosphere. It is safer to gauge by the dampness. It should be just damp enough to hold together without crumbling and not wet enough to allow any water to be pressed out of a handfull. The common fault is to make it too wet.

In larger joints extra precautions have to be taken, as they seem to leak much more than the smaller ones. The two surfaces against which the cement is driven should be cleaned of all rust, we used a foundry brush

One experience with dirty joints was sufficient. In order to change the position of a 20" inch main we burnt out about ninety lead joints. The lead in most cases was melted by the use of a 3/4 inch pipe curved to fit the main, and used as a bunsen burner. holes being drilled all along one side. After moving the main over some five feet to the new location all the joints were made up with cement and ninety five percent leaked, all apparently due to dust and burnt yarn in the joints.

The pipe should be placed in the trench upon blocking

which has previously been well bedded and settled as much as possible with a rammer. After lining up each pipe should be covered up as much as possible with dirt, care being taken to stamp the bottom and sides well. This is to hold the pipe rigidly and to keep it as cool as possible boards are placed over the joints.

The joint is now ready for the cement which is "stuffed" in, starting from the bottom up. The men use rubber mits to keep the cement from eating their skin. After working back as much cement as possible a second strand of yarn is twisted tight and driven into the

joint. This rope should be just as large as can be worked into the joint. the yarn binding upon the sides holds the cement more rigidly until it sets. The rest of the joint space is filled with another layer of cement leaving a small fillet out side.
The pipe should be covered immediately to prevent any rise in temperature with burlap bags or boards etc.
Having made up our minds that variation of temperature was the cause of numerous leaks while being laid, we decided upon placing one inch Hemlock boards over the whole pipe and covering with about

six inches of dirt. As long as the sun was shining, the dirt was sprinkled and kept damp. This method seemed to be very satisfactory, and in order to determine its efficiency, I made a set of temperature readings. A Bristol Recording Gauge was set in the ditch under the board cover. Another thermometer was hung just under the cover, called number 3. No 2 thermometer was placed just above the cover. No 1 being hung in the shade on the fence post. A comparison of the three gave the following results

	1ST READING.	2ND.	3RD READING.
No 1	92°	80°	57°
No 2	93°	81°	58°
No 3	94°	81°	59°

These three readings were taken to correct the thermometers. and were taken when the three bulbs were immersed in water together.

Readings were taken every hour for three days and nights.

Below is given the set of readings and also four curves showing a comparison of the readings.

TEMPERATURE READINGS.
29TH AND INDIANA, AVE.

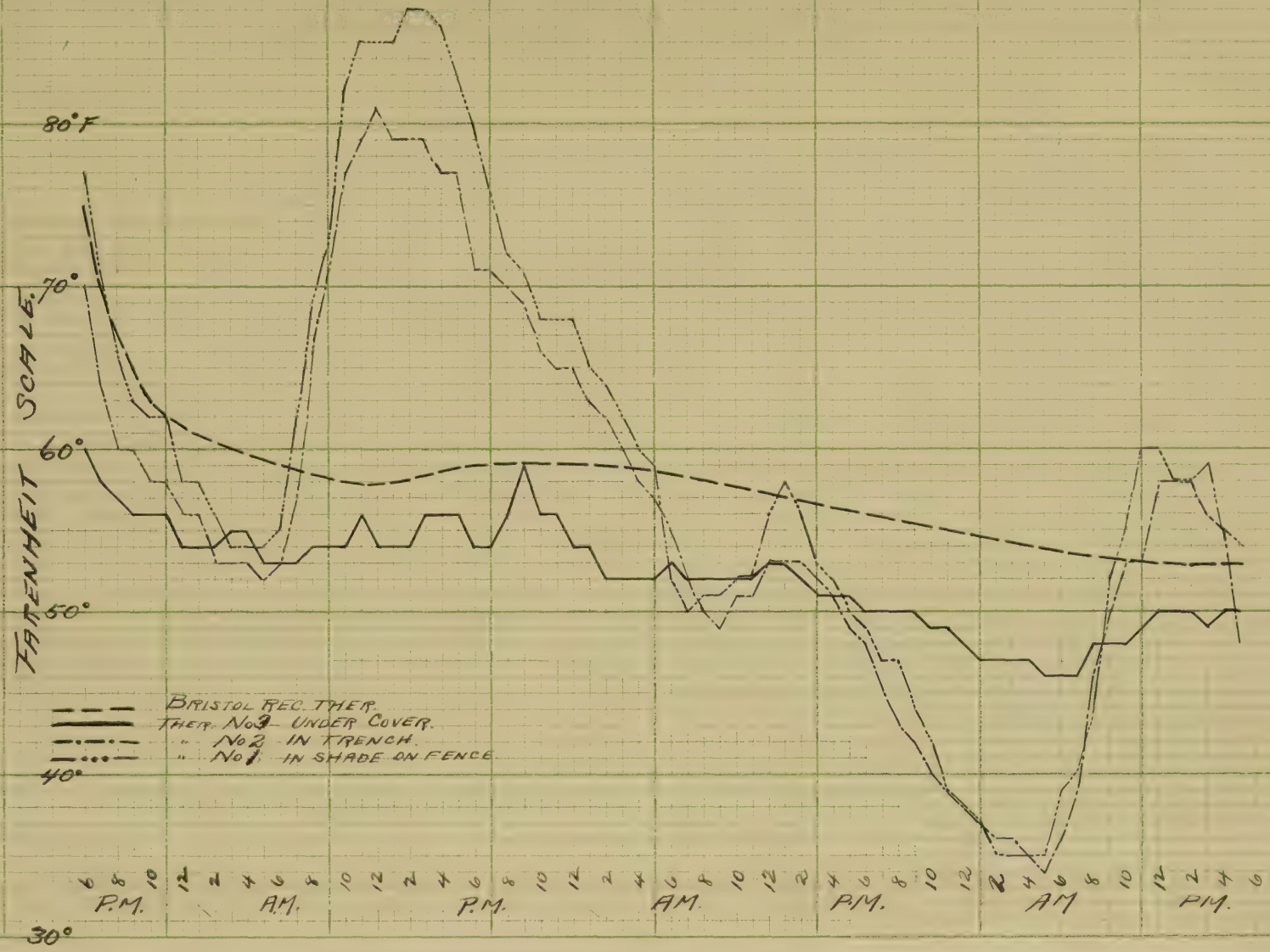
DATE: 4-29-03

TIME	No1	No2 READ	No2 CORREC	No 3 READ	No 3 CORR.	TIME	No1	No2 READ	No2 CORR	No3 READ	No3 CORR.
P.M.						AM 7	62	67	66	55	53
6	77°	71	70	62	60	8	69	72	71	56	54
7	71	65	64	60	58	9	72	78	77	56	54
8	66	61	60	59	57	10	82	78	77	56	54
9	63	61	60	58	56	11	86	80	79	58	56
10	62	59	58	58	56	12	86	82	81	56	54
11	62	59	58	58	56	PM 1	86	80	79	56	54
12	58	57	56	56	54	2	88	80	79	56	54
AM 1	58	57	56	56	54	3	88	80	79	58	56
2	56	54	53	56	54	4	87	78	77	58	56
3	54	54	53	57	55	5	84	78	77	58	56
4	54	53	52	57	55	6	80	72	71	56	54
5	54	54	53	55	53	7	75	72	71	56	54
6	55	58	57	55	53	8	72	71	70	58	56

BRISTOL'S RECORDING
Degrees Fahr.
Chart
No 700.
SET IN MAIN TRENCH.
4 FT. DEEP.
COVERED
THERMOMETER
SATURDAY
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
AM.
PM.
NOON
NIGHT
12
3
6
9

Time	No 1	No 2		No 3		Time	No 1	No 2		No 3	
		Read	Cor.	Read	Cor			Read	Cor.	Read	Corrected
P.M. 9	71	67	66	61	59	7	47	45	44	52	50
10	68	66	65	58	56	8	47	43	42	52	50
11	68	66	65	58	56	9	44	42	41	52	50
12	68	64	63	56	54	10	42	40	39	51	49
A.M. 1	65	63	62	56	54	11	39	39	38	51	49
2	64	61	60	54	52	12	38	38	37	50	48
3	62	59	58	54	52	A.M. 1	37	37	36	49	47
4	60	58	57	54	52	2	35	36	35	49	47
5	59	56	55	54	52	3	35	36	35	49	47
6	52	53	52	55	53	4	35	35	34	44	47
7	50	51	50	54	52	5	35	34	33	48	46
8	51	50	49	54	52	6	39	36	35	48	46
9	51	52	51	54	52	7	40	39	38	48	46
10	52	52	51	54	52	8	44	45	44	50	48
11	52	54	53	54	52	9	52	50	49	50	48
12	56	54	53	55	53	10	55	53	52	50	48
P.M. 1	58	54	53	55	53	11	60	53	52	51	49
2	56	54	53	54	52	12	60	58	57	52	50
3	53	53	52	53	51	P.M. 1	58	58	57	52	50
4	52	52	51	53	51	2	58	58	57	52	50
5	50	50	49	53	51	3	59	56	55	51	49
6	49	49	48	52	50	4	55	55	54	52	50
						5	54	48	47	52	50

Thermometer No3 and the recording thermometer were under the same conditions, being placed below the board cover and very close to the main. the recording one reads very high. although quite uniform and that is the object of the cover; to allow the cement


80°F
70°
60°
50°
40°
30°
FARENHEIT SCALE.
BRISTOL REC. THER.
THEIR. No3 - UNDER COVER.
" No2 IN TRENCH.
" No1 IN SHADE ON FENCE
6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6
P.M. A.M. P.M. AM. P.M. AM PM.

to set for twenty-four hours without being disturbed with excessive temperature changes.

The test covers the period between 6 P.M. Wednesday April 29th and 5 P.M. Saturday May 2nd. which included one very warm day and another cool one.

These results show that our covering of one inch boards and 3 to 6 inches of dirt is a most effective method of keeping the temperature of the joints constant.

The maximum variation of Thermometer No 1 for twenty-four hours being 38° while for No 3 under the cover it was only 9°

The results of using this covering on laying large mains with cement joints was about 1% of

the joints leaked as against 75% to 80% leaking without any covering and 30% leaking with burlap bag covering which was used on another large operation.

It is the practice in some other gas works to use one lead joint about every 200 ft in a line of pipe to allow for the contraction but our experience is that this is not necessary. On a line of 30 inch pipe laid last year a lead joint was made every eight lengths or 96 feet to allow for the expansion and contraction. A brick manhole was built around one of the joints to facilitate an examination. During the winter the joint was watched closely and the maximum contraction pulled the lead joint

out only $\frac{1}{16}$ inch which was slightly more than the contraction of one pipe. and it did not by any means take up the contraction of the whole 96 feet.

There have been several lines of large mains laid in Philadelphia using cement joints entirely, which have yet to show any signs of leaks. These were only 20" diameter and under. One 30" main laid a year ago has given considerable trouble. Every joint uncovered showed signs of leaking, the cement having a very slight crack on the upper side of the joint. It may be that this size joint is too large to make with cement. As this kind of a joint does not allow for any

expansion or contraction, the strains on the cement due to changes of temperature are quite large.

I have calculated the shearing stress per square inch upon the cement joint which would be necessary to overcome the contraction due to a change in temperature of 50° F. in the following manner.

Coefficient of Expansion-Cast. Iron - .00000556

Contraction per inch length for 50° F. .000278

Modulus of Elasticity for about 4000 lbs. 15,000,000.

Force per sq. inch required to balance contraction - 4170 lbs

Internal Diameter of Pipe Inch.	Thickness of Wall Inch.	Sectional Area. Sq Inches.	Total Force Exerted by 50°F. Variation of Temperature	Depth of Cem. Joint.	Outside Circum-ference of Pipe.	Shearing Force per Sq Inch on Cement.
6"	1/2"	10"	41.700	3	22.0	632. LBS.
12"	5/8"	25"	104.250	3	41.5"	837.
16"	5/8"	33	137.610	3	54.0	841.
20"	3/4"	49	204.330	3	64.5"	1056.
30"	7/8"	85"	344.450	3	100.0	1181.

Owing to the complex nature of a cement joint, I am unable to obtain from any books on hand the force required to injure the cement when held between to surfaces of cast iron as in the case of joints.

Kents Hand book - gives the following datta.

Portland Cement.	Tensil Strength.	Compressive.
10 days -	376# per □"	2910# per □"
20 "	420# "	3342# "
30 "	451# "	3724# "

Then in another book the adhesive strength of Portland Cement & Plate Iron after 28 days was given as 66 lbs per Sq. in.

Mr C. S. Snyder of the U. G. I. Co made some very rough tests of the adhesive strength of Portland Cement to Cast iron pipe and with five (5) experiments obtained an

average strength of 37 lbs per sq. inch. the force being exerted vertically to the surface.

He also placed a force of 8000 lbs equal to about 136 lbs per square inch. upon a 6 inch joint. in trying to pull it out. but it did not have the slightest effect.

Judging from the shape of a cement joint. as shown opposite page – the force required to break it would probably come decidedly nearer the compressive than the tensil strength as given in the above table.

Owing to the rigidity of cement joints it is not considered advisable to use them in the business section of town as they will not allow for sudden

jars or slight settlements of the surrounding earth. but will hold solid until the strain becomes great enough to break the pipe. It is simply of a question of preference. a broken main or a lot of leaking lead joints. A broken main surrounded by conduits and manholes is a very dangerous arrangement. while in the outskirts of town where there are no conduits or manholes. the broken main is preferred as the gas can escape into the air with out doing any damage and it can be located and repaired much more cheaply than uncovering each joint and recaulking the same as is the case when lead joints are used.

As rigidity is not a quality

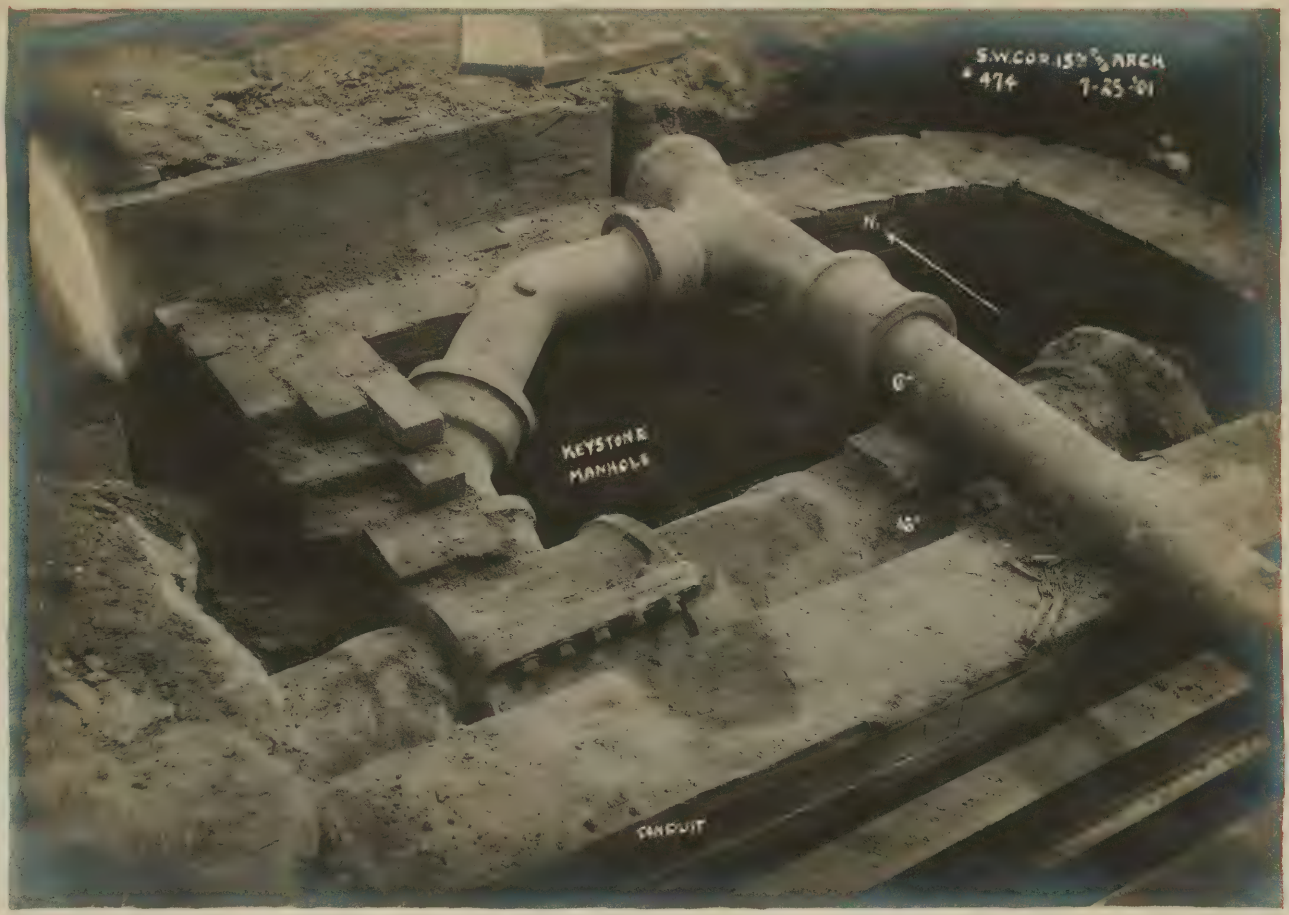
to be desired in the business section some form of expansion joint would be a very acceptable substitute for the time honored bell and spigot. There are several in the market but none seem to come up to the requirements of cheapness, simplicity of construction and efficiency.

BY- S. P. LEVIS.
U. G. I. Co PHOTOGRAPHER.

"HAT FLANGE" CONNECTION
30" TO 8"

U.G.I. PHOTOGRAPHER.

SHOWING OBSTACLES ENCOUNTERED.
ALSO - DRIP POT - AND USE OF CIRCLE BENDS



SHOWING "HUB SLEEVE" CONNECTION
16" TO 6" MAIN.
UNDER DIFFUCULT CIRCUMSTANCES.

GOVERNOR AND CONNECTIONS FOR NEW HOLDER
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